

High-Brightness Mid-IR Lasers Based on Virtual-Mesa Angled-Grating Distributed Feedback (α -DFB) and Photonic-Crystal DFB Structures

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Angled-grating distributed-feedback (α -DFB) lasers emitting in the mid-IR have displayed near-diffraction-limited output beams for relatively narrow ($W = 50$ mm) stripe widths. However, the beam quality degrades rapidly if W or the pump intensity of the Gaussian stripe is increased. The degradation has been attributed to the onset of Fabry-Perot like lasing modes facilitated by secondary pumping of the regions outside the stripe by mid-IR light for far-above-threshold operation. One way to prevent secondary pumping and thereby suppress the Fabry-Perot-like lasing is to selectively decrease the carrier lifetime in regions outside the pump stripe. We have accomplished this by bombarding either the entire regions on both sides of the stripe (the virtual mesa configuration) or strips near the facets (spoilors) with energetic silicon ions. Using measured far-field and simulated near-field characteristics, we have determined the beam quality enhancement for virtual-mesa and spoiler α -DFB lasers emitting at $3.6\text{ }\mu\text{m}$ and found that for stripe widths approaching the width of the opening, the beam quality is improved by nearly an order of magnitude for both geometries. Although the efficiency in the ion-bombarded α -DFB lasers was lower than the theoretical projections, the brightness was nonetheless enhanced by a factor of 3.

The α -DFB laser is in fact a special case of a more general class of photonic-crystal distributed feedback (PCDFB) lasers, in which the grating is defined on a two-dimensional lattice. In a properly designed PCDFB laser, the snake-like diffraction characteristic of the α -DFB is complemented by diffraction processes that couple the forward and backward-propagating beams. We predict that the latter processes will greatly improve the spectral selectivity of PCDFB lasers as compared to α -DFB devices, and also lead to much better beam qualities at very wide pump stripes. To test these predictions, we fabricated a rectangular-grating PCDFB with an aspect ratio of $\tan 20^\circ$, and compared its beam quality to that of an α -DFB laser processed from the same wafer. Whereas the α -DFB laser displayed little narrowing of the emission line as compared to a Fabry-Perot device, the spectral properties of the PCDFB laser are remarkably different. At temperatures for which the peak of the gain spectrum is in the vicinity of the cavity resonance, the laser line does not track the band gap variation, but switches between two cavity modes at 4.6 and $4.7\text{ }\mu\text{m}$. At $T = 240\text{ K}$, the pulsed emission FWHM is only 7 nm , as compared to 69 nm for the Fabry-Perot laser fabricated from the same material. Furthermore, the PCDFB beam quality is substantially improved compared to the α -DFB lasers, e.g., by as much as a factor of 5 at $W = 200\text{ }\mu\text{m}$, where the etendue is only 4 times the diffraction limit.